THE ESTABLISHMENT OF SHORTLEAF PINE FOLLOWING REPEATED PRESCRIBED BURNS AT CATOOSA WMA

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Abstract—A mature shortleaf pine (*Pinus echinata*) stand on the Cumberland Plateau in Tennessee at the Catoosa Wildlife Management Area was harvested in 2001 in response to a regional southern pine beetle outbreak and converted into a savannah through periodic prescribed burns in 2005, 2010, and 2013. Following the harvest and series of burns, the stand was occupied by shortleaf pine seedlings and saplings of different sizes (<5 feet, 6 to 10 feet, and >10 feet) at a rate of approximately 400 stems per acre. Given the re-sprouting capability of shortleaf pine, the objective of this study was to assess the age of the shortleaf pine regeneration to determine if establishment occurred progressively over time in conjunction with known prescribed burn dates or during a single event prior to, during, or after the timber harvest in 2001. Shortleaf pines from each height class were aged above-ground level and below-ground level at or just above the basal crook to determine when they initiated and if and when they re-sprouted. An analysis of variance and post-ANOVA mean separation were used to determine differences amongst mean ages of each height class. Shortleaf pines from all three height classes had similar below-ground ages of approximately 13 years, indicating that they were of a single cohort initiating around the time of the 2001 timber harvest ($p=0.4104$). While shortleaf pines in the 6- to 10-foot height class and the >10-foot height class had similar above-ground ages of 12 and 10 years respectively, shortleaf pines currently less than five feet tall were significantly younger above-ground, averaging 6 years in age ($p<0.001$). Shortleaf pines currently less than five feet in height were more than likely top-killed in the 2005 prescribed burn and have since re-sprouted, while those currently greater than five feet tall were more than likely not top-killed in the 2005 burn. The fluctuations in age and growth of regenerating stems of shortleaf pine in this study are indicative of the mosaic of stand burns and their impact across the stand.

INTRODUCTION

Shortleaf pine (*Pinus echinata*) is a fire-adapted species, in that it possesses the ability to re-sprout following top-kill. The J-shaped basal crook, a physiological trait unique to shortleaf pine amongst most other southern pine species, occurs just below the ground surface and contains numerous dormant buds that are capable of sprouting when top-kill from a disturbance, such as fire, occurs (Mattoon 1915, Guldin 1986). This conveys shortleaf pine a competitive advantage over species that do not re-sprout. Shortleaf pine historically occupied the widest range of southern pine species, stretching across approximately 16.5 million acres of the eastern United States (Smith 1986).

Over the past 50 years, however, shortleaf pine populations have declined up to 50 percent due to a combination of active fire suppression, land conversion, beetle outbreaks, and selective timber harvesting (Guldin and others 1999, South and Buckner 2003). Today's shortleaf pine dominated forests are older and of larger diameter classes, with comparatively low occurrences of early successional shortleaf pine forests (Oswalt 2012). This signals further difficulties of sustaining shortleaf pine across its native range. Efforts to restore the shortleaf pine ecosystem have largely focused on prescribed fire as a beneficial management tool, because of the species' re-sprouting capabilities, the fire-adapted requirements of associated vegetation, and historical wildfire regimes (Guldin and others 2004, Bukenhofer and Hedrick 2013). The overall impact of prescribed fire on shortleaf pine establishment, however, is not fully understood. Research has shown that bark thickness, seedling age, seedling size, and fire intensity can all impact the re-sprout success and survival of shortleaf pine following prescribed burning (Lilly and others 2012, Clabo 2014).

In order to investigate shortleaf pine establishment and re-sprouting in response to disturbances, such as overstory harvesting and prescribed burns, a case study was conducted at the Catoosa Wildlife Management Area on the Cumberland Plateau in East TN during the fall of 2014. The study site was a mature shortleaf pine stand until harvest in 2001, and is currently an open-savannah type community with

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various heights of shortleaf pine regeneration. Given the re-sprouting capability of shortleaf pine, the objective of this study was to assess the age of the shortleaf pine regeneration to determine if establishment occurred progressively with time in conjunction with known prescribed burn dates in 2005, 2010, and 2013 or during a single event prior to, during, or after overstory removal in 2001.

METHODS

Sites

The study site for this research was located at the Catoosa Wildlife Management Area (WMA) in Cumberland County, TN, within the Cumberland Plateau physiographic region. The study was conducted in Unit S41-North at Catoosa WMA, which is presently an open savannah-type community, last prescribed burn in February/March of 2013, with a minimal overstory occupied by scattered residual oaks and a midstory dominated by varying heights of shortleaf pine regeneration at a rate of approximately 400 stems/acre. Three general height classes characterize the shortleaf pine regeneration: one to five feet, six to ten feet, and greater than ten feet. All shortleaf pines were generally shorter than 16 feet. Woody vegetation accounted for 10 to 20 percent of the area, composed of shortleaf pine, red maple (*Acer rubrum*), southern red oak (*Quercus falcata*), scarlet oak (*Quercus coccinea*), post oak (*Quercus stellata*), sourwood (*Oxydendrum arboreum*). Sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), black cherry (*Prunus virginiana*), hickory (*Carya spp.*), viburnum (*Viburnum spp.*) and flowering dogwood (*Cornus florida*) occurred infrequently in the area. Annuals and perennials such as forbs, composites, and legumes, composed 5 to 10 percent of the plot cover, primarily represented by *Rubus spp*. Various grasses composed the remaining 75 percent of the plot cover.

Unit S41-North was harvested in 2001 in response to a southern pine beetle outbreak. Shortleaf pine dominated the pre-harvest stand, with an average DBH of 16 inches and basal area of 100 feet^2/acre, with scattered Virginia pine (*Pinus virginiana*) and various oak species (*Quercus* spp.). All shortleaf pines were removed in 2001, while the majority of oaks were left standing. An intense late-growing season burn, deemed the “Halloween Burn”, was performed in the stand on October 31, 2005. The “Halloween Burn” was particularly intense and burned hotter than anticipated, likely due to the higher fuel loads of leftover woody debris from the 2001 timber harvest and the drier conditions normally associated with late growing season burns. The majority of leaf litter and duff were consumed, exposing mineral soil across the stand. Subsequent early-growing season burns of lower intensity were conducted in February/March of 2010 and 2013. These fires were cooler and did not expose the mineral soil, suggesting that they had a much lesser impact. The three prescribed fires conducted over this time period probably impacted the development of shortleaf pine regeneration across Unit S41-North to varying degrees.

PROCEDURES

Data Collection—To determine the age of establishment and sprouting in relation to disturbance history, shortleaf pine regeneration from each height class were destructively sampled and aged just above-ground level and below-ground level at or just above the basal crook. Within Unit S41-North, three parallel transects were established two chains apart. Three points, each two chains apart, were sampled along each transect line for a total of nine points. All distances were measured using standard pacing techniques. At each point along the transects, the closest height class one, Ht1 (one to five feet); height class two, Ht2 (six to ten feet); and height class three, Ht3 (greater than ten feet) shortleaf pines were collected. This procedure produced nine total samples from each height class and 27 samples overall (table 1).

When more than one sprout occurred on a single sample, the most dominant sprout was selected.

Table 1—Height class distribution and sample sizes of shortleaf pine regeneration in Unit S41-North of Catoosa WMA in Cumberland County, TN, 2014

Height Class	Stems per acre	Sample Size (n)
Ht1 (1-5ft)	98	9
Ht2 (6-10ft)	168	9
Ht3 (10ft+)	127	9
Total	393	27

Samples were cut to a more manageable size, both above-ground and below the basal crook. Each sample was labeled according to its specific transect point and height class, then taken to the lab for further analysis. To determine the density of shortleaf pine by height class, 26 1/20th acre plots were allocated equidistantly along three additional transects. Shortleaf pines were counted within each plot and categorized into the same three height classes used for age classification. Sample collection and field measurements occurred on November 7, 2014.

In the lab, the samples were cut with a band saw to reveal clean cross-sectional faces just above-ground level and below-ground level at or just above the basal crook. Each sample face was sanded with a belt sander until the growth rings were clear enough that the sample could be properly aged both above- and below-ground level. Using a magnifying lens and a 50x stereo microscope, the growth rings of both sides of each sample were counted. Due to the possibility of observer bias, multiple researchers independently aged each sample. An above-ground age and a below-ground age was determined for each sample, to differentiate between the sample's effective age, or sprout age, and its true age, or rootstock age. The sample preparation and aging took place during the week of December 1 - 5, 2014. Shortleaf pine sample ages were referenced to known dates of the overstory harvest and the prescribed burns.

Statistical Analysis

Analysis of variance (ANOVA) was employed to test for differences in above- and below-ground ages between height classes. A significance level of 5 percent was used. Following a significant ANOVA test, mean separation procedures were conducted utilizing Bonferonni's method to determine which height classes significantly differed.

RESULTS

Shortleaf Pine Density

Across Unit S41-North, shortleaf pines in Ht1 occurred at a rate of 98 stems per acre. Ht2 occurred at a rate of 168 stems per acre, and Ht3 occurred at a rate of 127 stems per acre. Overall shortleaf pine density equaled 393 stems per acre (table 1).

Shortleaf Pine Aging

The average ages of Ht1 were 6 years above-ground and 12 years below-ground (table 2). The average ages of Ht2 were 12 years above-ground and 14 years below-ground. The average ages of Ht3 were 10 years above-ground and 12 years below-ground.

The mean below-ground ages for all three height classes did not significantly differ ($p = 0.4104$). Ht1, Ht2, and Ht3 all had statistically similar below-ground ages (table 2). The mean above-ground ages for all three height classes did significantly differ ($p < 0.001$). The above-ground ages for Ht2 and Ht3 did not differ. However, Ht1 had a significantly younger above-ground age than Ht2 and Ht3.

The below-ground ages for all three height classes, 12 years, 14 years, and 12 years respectively, all occurred around the time of the 2001 overstory harvest 13 years ago. The mean above-ground ages for Ht2 and Ht3, 12 years and 10 years respectively, date to prior to the intense prescribed burn in 2005. The mean above-ground age for Ht1, 6 years, dates to after the 2005 prescribed burn occurred.

DISCUSSION

The similarity in below-ground ages for all three height classes reveals that the majority of shortleaf pine regeneration in Unit S41-North is of a single cohort, established 12 to 13 years ago, shortly after the timber harvest in 2001. The conditions following the timber

Table 2—Mean above- and below-ground ages and ANOVA results for three height classes of shortleaf pine regeneration in Unit S41-North of Catoosa WMA in Cumberland County, TN, 2014

Height Class	Below-ground age (yrs.)	Std. Dev.	Above-ground age (yrs.)	Std. Dev.
Ht1 (1-5ft)	12a[1]	4.6	6a	2.7
Ht2 (6-10ft)	14a	3.9	12b	3.7
Ht3 (10ft+)	12a	2.9	10b	1.9

[1] Means within each column not followed by same letter differ significantly at P = 0.05.

harvest would have been conducive for shortleaf pine re-establishment, with a residual seed source from the recently removed mature trees, an open canopy, and exposed mineral soil from the harvesting operations.

The differences in above-ground ages suggest that Ht1 pines were significantly younger than Ht2 and Ht3 pines. In relation to the 2005 prescribed burn, Ht1 had above-ground ages younger than the burn, while Ht2 and Ht3 had above-ground ages older than the burn. This occurrence is representative of the mosaic of impact that prescribed fire displays across a landscape. Shortleaf pines currently in Ht2 and Ht3 were more than likely not top-killed in the 2005 prescribed burn. This would explain why these pines are in the taller height classes. However, shortleaf pines currently occupying Ht1 were more than likely top-killed in the 2005 prescribed burn and have since re-sprouted, explaining why these pines are in the shortest height class. A large percentage of the initial cohort that regenerated after the 2001 timber harvest likely were killed entirely by the 2005 prescribed burn. Other studies have concluded that only 40 percent of shortleaf pine seedlings will re-sprout after top-kill and that the likelihood of re-sprouting decreases with increasing age and size (Lilly and others 2012, Clabo 2014). A similar scenario probably occurred on this study site.

The results of this study suggest that the 2005 prescribed fire was of varying intensity and impacted shortleaf pines differently across the landscape. Many shortleaf pine seedlings that regenerated after the 2001 timber harvest were likely killed entirely by the 2005 burn, while other seedlings were only top-killed and re-sprouted or were minimally impacted and not top-killed. This "mosaic" of fire impact across the landscape could be explained by variations in fuel loads and environmental conditions, specifically micro-topography and moisture levels, between microsites. Shortleaf pines occurring on more favorable, less-exposed, wetter, concave microsites had a greater chance of withstanding the impacts of fire than those occurring on less favorable, more-exposed, drier, convex microsites. The burns occurring in 2010 and 2013 seemed to have a much less dramatic impact on the shortleaf seedlings, but likely produced a similar mosaic of impact across Unit S41-North. Another important observation from this study is that periodic burning did not create new cohorts of shortleaf pine. A viable seed source was not present in this stand or adjacent stands once the shortleaf pine overstory was removed.

The results of this case study stem from a small sample size and reflect only a fairly small portion of the 80,000 acre Catoosa WMA with unique circumstances of a sanitation harvest prior to southern pine beetle and the resulting creation of a savannah through a series or prescribed fires. Only current vegetation was available to sample, making it difficult to characterize the vegetation and shortleaf pine density before the 2005, 2010, and 2013 burns.

SILVICULTURAL IMPLICATIONS

Prescribed burning can be a useful tool when managing shortleaf pine stands for site preparation, hardwood competition control, and the maintenance of fire-dependent, associated species, such as bluestem (*Andropogon spp.*). Site preparation is perhaps the most applicable use of prescribed fire in shortleaf pine stands, as a well-conducted burn can expose mineral soil and improve regeneration conditions. However, burning does not create new cohorts in the absence of an active shortleaf pine seed source. For this reason, it can be assumed that burning too frequently in young stands could lead to a decline in the shortleaf pine component. If shortleaf pine restoration is a goal in stands where no seed source exists, planting may become necessary. Burning promotes a mosaic of vegetational structures across a stand or landscape. Microsite variations have unavoidable influence on prescribed burning. The results of this study suggest that burning prior to 5 years of age encourages top-kill and re-sprouting, but the overall re-sprout rate of shortleaf pine remains unknown. Prescribed burning can play a key role in shortleaf pine management regimes, but the results of the practice are highly variable with an array of impacts on the structure of the vegetation.

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